

# COPPER, CHROMIUM, AND ARSENIC LEVELS IN SOILS SURROUNDING POSTS TREATED WITH CHROMATED COPPER ARSENATE (CCA)

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## ABSTRACT

The levels of copper, chromium, and arsenic in soil surrounding CCA-treated posts and beneath CCA-treated stakes were investigated at a plot near Gainesville, Florida. Metal levels were elevated in soil immediately adjacent to the treated wood, but decreased with distance away or depth. Mean extractable arsenic levels ranged from 1.74 to 8.19 ppm immediately adjacent to the posts, but declined to less than 1 ppm in samples 150 and 300 mm away, regardless of depth sampled. The results suggest that soil contamination due to the presence of CCA-treated wood for 45 years is minimal.

*Keywords:* CCA, migration, soil, wood preservation, chromium, copper, arsenic.

## INTRODUCTION

Chromated copper arsenate (CCA) was developed for wood treatment in the mid-1930s in India (Hartford 1973). Initially, this preservative was used sparingly, but preferences for exterior living spaces such as decks and balconies in U.S. homes in the late 1950s created a demand for treatments to increase wood durability while leaving a clean, paintable surface. The preservatives available at that time (primarily pentachlorophenol and creosote) left an oily coating on the surface and had an unpleasant odor, making them unsuitable for this purpose. Demand for CCA-treated wood for these applications fueled enormous growth in the production of treated wood, which lasted well into the 1980s. At the same time, how-

ever, changing environmental concerns encouraged closer examination of the use of all pesticides, including those used for wood treatment (USDA 1980). A re-examination of CCA for wood treatment by the U.S. Environmental Protection Agency concluded with the decision to restrict the use of this chemical, but not wood treated with this product.

The use of CCA continued to be scrutinized by a number of regulatory agencies, but most concluded that the use of wood treated with this product had little or no negative impact on the environment when used and disposed of properly.

Unlike many of its predecessors, CCA is more of a 'designer preservative' in that its components were each added to serve specific purposes (Hartford 1973). Copper is broadly toxic in an array of life forms, arsenic is an insecticide that also provides supplemental

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protection where copper-tolerant fungi are present, and chromium reacts with the wood as well as copper and arsenic to reduce the potential for leaching losses once the wood is in service and also minimizes the corrosion of metal fasteners. Although often referred to as "fixed," some levels of the individual CCA components are always in solution in free water within the wood cell lumens. This solubilized metal can leach from the wood over time, albeit at very slow rates, and it is these leachable components that have raised concerns among CCA users.

When examined separately, there are toxicity issues for certain forms of each component in CCA. For example, hexavalent chromium, which is present in the treatment solution, is a known carcinogen. Hexavalent chromium is reduced to the much less toxic trivalent state in the wood. This rate of reduction is dependent on temperature following treatment, with faster reduction occurring at higher temperatures. Copper is broadly toxic at high levels, but the primary concern with the use of copper-based systems is their toxicity in aquatic environments. Arsenic is widely perceived to be the worst of the three CCA components, stemming from its use as a poison in many murder mysteries (Parris 2000). Arsenic is a known carcinogen, and this element has received considerable worldwide attention focusing on its presence in drinking water and its risk to humans (Nordstrom 2002).

Several CCA formulations are listed in the Standards of the American Wood Preservers' Association (AWPA 1999b), but the most commonly used CCA formulation contains approximately 47.5% chromium trioxide, 18.5% cupric oxide, and 34% arsenic pentoxide (CCA Type C) (AWPA 1999b). CCA is normally specified on an oxide basis; therefore, translating these to elemental levels would result in 1 kg of CCA containing 247 g of chromium, 146 g of copper, and 220 g of arsenic. The treatment in the wood is typically expressed on the basis of biocide weight per wood volume. For residential soil contact applications, the CCA retention is specified to be

6.4 kg/m<sup>3</sup> on an oxide basis (AWPA 1999a). As a result, each cubic meter of treated wood contains 1.58 kg of chromium, 0.93 kg of copper, and 1.41 kg of arsenic.

After wood is treated with CCA, the preservative normally undergoes a series of reactions with the wood. The chromium is reduced, copper reacts with both the wood and the chromium, and the arsenic reacts with both the chromium and the copper (Dahlgren and Hartford 1972a, b, c; Dahlgren 1974; Pizzi 1982). The most easily measured reaction is the reduction of hexavalent chromium, and tests have been developed for detecting this chemical in wood. The reaction rates differ with wood species and treatment solution concentrations, but the most important factor is temperature. Fixation usually occurs within days at warmer temperatures, but fixation can pose a major challenge for treaters operating in colder climates.

Although fixation has long been viewed as permanent, CCA components do migrate from the wood over time (Cooper 1994; Cooper and Ung 1997; Jin et al. 1992). The most significant losses occur shortly after installation when unfixed components on the surface leach into the surrounding environment. The losses from CCA-treated wood have generally been studied by water immersion, owing to greater concerns about the risks of copper to aquatic organisms. Migration into soil surrounding treated wood has received far less attention, although it is not a new concern (Mortimer 1991). Muraka et al. (1996) studied pentachlorophenol (penta) in soil around penta-treated utility poles and found little evidence of migration beyond 300 mm from the poles. The recent concerns about the use of CCA-treated wood in Florida have highlighted the lack of data on the migration of CCA components from treated wood into soil (Matus 2001; Solo-Gabriele et al. 1999; Townsend et al. 2000; Conklin 2001). Although such data can be developed by installing freshly treated, properly fixed wood into soil and monitoring subsequent metal levels, this approach takes too long to supply meaningful data in the time

required by regulators to make informed decisions concerning the handling of wood treated with this preservative. An alternative to developing new data is to take advantage of materials that have been previously installed. In most cases, this material is unsuitable for testing because of the lack of adequate characterization prior to installation. The exceptions are field tests that have been used to develop new preservatives. For example, DeGroot et al. (1979) examined soil surrounding CCA-treated southern pine stakes in Saucier, Mississippi, and found elevated metal levels within 75 mm of the stakes. The Austin Cary Forest at the University of Florida is another site where most of the wood preservatives developed over the past 50 years have been evaluated prior to commercialization. While many of the systems tested are proprietary, some of the tests are public and contain test samples that could be used to assess preservative migration into soil over time. Among these are a 1954 test of CCA-treated posts and a 1957 test of CCA-treated dimension lumber stakes.

In this report, we assessed metal levels in soil surrounding and beneath CCA-treated wood as well as in the wood from these two tests.

#### MATERIALS AND METHODS

Southern pine posts that had been treated to a retention of either 8 or 12 kg/m<sup>3</sup> with a formulation of CCA similar to the currently used Type B were installed at the Austin Cary Memorial Forest in 1954. Type B CCA contains higher levels of arsenic and lower levels of chromium than the more commonly used Type C formulation. This should make the system less strongly fixed and more prone to metal losses (Henry and Jeroski 1967). The posts were part of a larger evaluation of CCA. Half of the posts sampled had been in the plot for the entire 47-year exposure period, while the remainder had been removed for 7 months (the posts were stolen), set into another site, then recovered and returned to their original holes. Although the removed posts were set into their

original holes, it was impossible to avoid some soil disturbance around the holes. As a result, we might expect slightly different soil metal characteristics around these posts.

The test site is typical of northern Florida scrub forest and contains palmetto and other brush beneath a southern pine and mixed hardwoods overstory. The soil has been described as poorly drained, siliceous, hyperthermic, and ultic haploquod of the Pomona Sand Series. The surface pH measured 4.47 and the water-holding capacity was 8%. The A horizon (0 to 100 mm) was dark grey sand (Munsell Color Notation: 10 YR 3/1), having a weak fine crumb structure, very friable and extremely acidic. The E1 horizon (100 to 500 mm) was grey sand (10 YR 7/2) single-grained, loose, and also strongly acidic. The next layer (500 to 650 mm) was dark brown (5 YR 2.5/2), sand, moderate to granular structure. This layer adsorbs significant amounts of trace metals due to the presence of organic materials and aluminum. The E2 horizon, extending from 650 to 1,500 mm (10 YR 8/1), was single-grained, loose and light-colored and had little ion retention capacity. The 1,500- to 1800-mm layer was tan/yellow (2.5Y 6/2) silt/clay that absorbs metals due to its high surface area. This layer had distinct brownish yellow mottles (10 YR 7/8). The site was hand-cleared of palmetto prior to sampling, taking care to minimize surface disturbance.

#### *Soil sampling*

A soil auger was used to sample the soil around each post, with soil samples collected based upon both horizontal distance away from the wood and vertical depth at that horizontal location. Soil cores were removed from three equidistant locations around each post immediately adjacent to the wood, as well as 150 and 300 mm away. Soil in individual cores was collected from depth zones corresponding to 0–25, 150–175, 300–325, and 425–450 mm from the surface. The three samples from the same depth and distance from the post were combined for a given post. Five

posts were sampled for each retention and condition (original or replaced). In addition to the radial sampling pattern, two posts (treated to 12 kg/m<sup>3</sup>) were carefully removed from the ground, and the soil auger was used to remove soil from directly beneath the posts, as well as 300 and 1,200 mm below the post, to determine whether metal losses were potentially higher from the end grain of the wood in direct soil contact. The end grain of the post should absorb higher levels of initial treatment, which might be more vulnerable to migration into the soil. In addition, the post would protect any migrating chemicals from downward water flow through the sandy soil.

Background metal levels in soil were assessed by digging a soil pit away from the stake tests. Samples were collected from the surface, then approximately 300, 600, 900, and 1,200 mm beneath the surface. The 900-mm layer coincided with an alumina layer that was believed to contain higher levels of soil minerals.

The soil samples (10 g) were extracted in 20 ml of 0.025 M diethylenetriaminepentaacetic (DTPA) for 2 hours on a mechanical shaker (Anonymous 1989). The extract was filtered through Whatman No. 42 filter paper; then the resulting extract was analyzed for metal content by ion-coupled plasma spectroscopy (ICP), and the results were compared with prepared standards, as well as blank samples containing only DTPA.

The soil analyses were subjected to an ANOVA using a General Linear Model to determine whether the differences in metal levels around the posts differed statistically with depth and distance for posts treated to a given retention.

#### *Wood sampling*

Sixteen posts were selected for study. Eight of the posts had been treated to an initial retention of 8 kg/m<sup>3</sup>, while the remainder had been treated to 12 kg/m<sup>3</sup>. Four of the posts in each treatment group had been at the original

site since installation; the remainder had been removed and reinstalled as described earlier.

Increment cores 50 mm long were removed from the posts at sites approximately 150 mm below groundline and 300 mm above groundline. These cores were divided into the outer and inner halves. Three increment cores were taken from each height for each post.

In addition to the post sampling, four 2- by 4- by 18-inch stakes treated to 23–24 kg/m<sup>3</sup> with CCA and installed in 1957 were sampled by removing the stakes and using the soil auger to collect soil samples from immediately below the stake, and 450 mm, 900 mm, and 1350 mm below the end of the stake.

Wood samples were microwave digested and analyzed according to previously described procedures (Gaviak et al. 1994). Briefly, 500 mg of material was placed in a 120-ml teflon digestion vessel; 0.5 ml of trace metal grade concentrated nitric acid and 2 ml of 30% hydrogen peroxide were added to each vessel; then the samples were predigested for 30 minutes. The samples were then capped and microwaved for 4 minutes at 296 watts, then 8 minutes at 565 watts. The samples were transferred to a centrifuge tube and the volume was adjusted to 15 ml with dionized water. The samples were then analyzed by ICP.

#### RESULTS AND DISCUSSION

Copper, chromium, and arsenic levels in the control soil pit were all uniformly low, a finding that is consistent with the inability of sandy soils to sorb and retain metals. Interestingly, even the alumina layer at about 1,000 mm from the surface had relatively low metal levels. We originally excavated to this depth with the understanding that this layer would tend to sorb any metals that moved downward in the soil column (Table 1). These low metal levels suggest that either little metal migrated downward or that this layer was unable to trap the metals.

#### *Metal levels in soil around posts*

Soil types can strongly influence metal solubility, although the effects do not necessarily

TABLE 1. *Copper, chromium, and arsenic levels at selected depths in a soil pit dug in native soils in the Austin Cary Memorial Forest located away from any possible source of CCA.*

Sampling depth (mm)	Metal level (ppm)		
	Copper	Chromium	Arsenic
0–25	0.40	<0.02	0.13
300–325	0.10	<0.02	<0.05
600–625	0.10	0.04	0.21
900–925	0.10	<0.02	0.38
1200–1225	0.10	<0.02	<0.05

mean that preservative components will migrate differently in differing soils (Schultz et al. 2002; Cooper et al. 2001; Wang et al. 1998). Copper tended to be present at the highest levels of all three elements, particularly near the soil surface immediately adjacent to the posts. Copper levels declined significantly, over 6-fold from the upper surface to the deepest sampling zone nearest the posts (*P* value < 0.0001), but these levels were still well above the background level found in the soil pit (Tables 1 and 2). Movement of some posts from each treatment had negligible effects on chrome levels in the surrounding soil, but copper and arsenic levels were sometimes much lower immediately adjacent to the posts. The lower levels might reflect losses that occurred during exposure at the other site, but would be impossible to determine because of the inability to sample the other site.

Copper levels in soil were significantly higher in soils surrounding posts treated to higher retentions. Copper levels 150 mm away from the posts declined significantly from those immediately adjacent to the posts. Copper levels 300 mm away from the posts were again lower at the surface, but copper levels deeper in the soil were similar to those found at corresponding zones 150 mm away from the post. The lack of further declines in copper level with distance from the post may reflect the close proximity of the posts in the plots. The posts were generally set approximately 0.9 m apart in rows, but some posts were closer together and it is possible that chemical mi-

TABLE 2. *Copper levels in soils at selected depths and distances from southern pine posts treated with chromated copper arsenate (Type B).<sup>a</sup>*

Location Retention/post history	Residual metal level (ppm) at each sampling depth (mm)														
	0–25 mm (next to post)			150 mm from post			300 mm from post			300 mm from post					
	0–25 mm	150–175 mm	300–325 mm	0–25 mm	150–175 mm	300–325 mm	450–475 mm	0–25 mm	150–175 mm	300–325 mm	450–475 mm	0–25 mm	150–175 mm	300–325 mm	450–475 mm
8.0 kg/m <sup>3</sup>															
Original	253.5 (137.3)	39.5 (23.0)	31.0 (6.5)	17.9 (17.4)	1.5 (0.7)	1.0 (0.8)	1.5 (1.0)	1.5 (0.9)	1.1 (0.2)	2.8 (3.9)	1.2 (0.9)	1.5 (0.9)	1.1 (0.2)	2.8 (3.9)	1.2 (0.9)
Replaced	144.4 (70.0)	36.0 (25.3)	30.0 (22.6)	7.8 (6.0)	5.7 (5.7)	2.4 (1.7)	4.9 (3.6)	1.6 (0.1)	3.8 (4.5)	5.6 (6.9)	5.9 (8.1)	1.6 (0.1)	3.8 (4.5)	5.6 (6.9)	5.9 (8.1)
12.0 kg/m <sup>3</sup>															
Original	301.0 (301.3)	28.5 (27.7)	28.0 (19.2)	3.2 (1.9)	1.3 (0.7)	0.9 (0.5)	2.0 (2.9)	2.2 (1.9)	0.3 (0.2)	1.5 (1.8)	0.9 (0.9)	2.2 (1.9)	0.3 (0.2)	1.5 (1.8)	0.9 (0.9)
Replaced	201.4 (147.2)	33.7 (26.2)	41.2 (13.1)	19.5 (18.6)	3.0 (3.9)	2.3 (2.4)	5.8 (6.6)	1.0	<0.1	0.4	1.4	1.0	<0.1	0.4	1.4

<sup>a</sup>Numbers in parentheses represent one standard deviation. Where no standard deviation appears, only one sample was analyzed.

gration from one post may have overlapped with that of an adjacent post.

Chromium levels were generally low for all of the soil locations and depths sampled and ranged from 0.36 to 0.56 ppm immediately adjacent to the high-retention posts and 0.51 to 0.86 ppm next to the low-retention posts (Table 3). Chromium levels were at background levels 150 and 300 mm away from the posts. As with copper, the chromium levels decreased significantly with distance away from the post and depth beneath the surface, for each retention. The low chromium levels in the soil reflect the strong reactions of this metal with the wood. As a result, we would expect little chromium to be present in the surrounding soil.

Arsenic levels were elevated immediately adjacent to the posts near groundline, then declined with both depth and distance (Table 4). These differences, however, were not significant. Elevated arsenic levels immediately adjacent to the posts were not surprising, given the high initial levels of arsenic in the preservative. Background arsenic levels ranged from 0.13 to 0.38 ppm. Arsenic levels 150 and 300 mm from the posts were similar to or slightly above the background level.

Overall, metal levels in the soils surrounding the Florida posts were lower than those found in the previous study in Mississippi (DeGroot et al. 1979). The differing site characteristics and the use of sawn vs. round material treated to slightly different retentions all make it difficult to infer much from these differences. The extraction method may have also influenced results. DTPA tends to extract available metals and may underestimate total metals in the soil.

#### Preservative levels in posts

The posts were originally treated to target retentions of 8 and 12 kg/m<sup>3</sup>, both levels that exceed the currently recommended 6.41 kg/m<sup>3</sup> for wood used in soil contact for residential construction (Table 5). Preservative levels tended to be higher in the outer 12 mm of the

TABLE 3. Chromium levels in soils at selected depths and distances from southern pine posts treated with chromated copper arsenate (Type B).<sup>a</sup>

Location Retention/post history	Residual metal level (ppm) at each sampling depth (mm)																							
	0-25 mm (next to post)			150 mm from post			300 mm from post			300-325 mm			450-475 mm											
8.0 kg/m <sup>3</sup>	0.47	(0.09)	0.94	(0.33)	0.76	(0.14)	0.85	(0.32)	0.09	(0.08)	0.05	(0.02)	0.07	(0.05)	0.11	(0.08)	0.03	(0.01)	0.05	(0.03)	0.05	(0.03)	0.03	(0.02)
Replaced	0.54	(0.28)	0.77	(0.21)	0.70	(0.11)	1.02	(0.38)	0.09	(0.03)	0.15	(0.19)	0.05	(0.02)	0.07	(0.02)	0.06	(0.05)	0.06	(0.02)	0.04	(0.00)	0.04	(0.02)
12.0 kg/m <sup>3</sup>	0.50	(0.26)	0.40	(0.28)	0.36	(0.18)	0.27	(0.03)	0.04	(0.02)	0.05	(0.03)	0.07	(0.05)	0.03	(0.01)	0.04	(0.03)	0.03	(0.02)	0.03	(0.01)	0.05	(0.03)
Replaced	0.46	(0.10)	0.72	(0.51)	0.62	(0.16)	0.44	(0.19)	0.08	(0.04)	0.03	(0.01)	0.03	(0.01)	0.08	(0.05)	0.03	(0.03)	0.02	(0.02)	0.02	(0.02)	0.02	(0.03)

<sup>a</sup> Numbers in parentheses represent one standard deviation. Where no standard deviation appears, only one sample was analyzed.

TABLE 4. Arsenic levels in soils at selected depths and distances from southern pine posts treated with chromated copper arsenate (Type B).<sup>a</sup>

Location Retention/post history	Residual metal level (ppm) at each sampling depth (mm)												
	0-25 mm (next to post)			150 mm from post			300 mm from post			450-475 mm			
	0-25 mm	150-175 mm	300-325 mm	0-25 mm	150-175 mm	300-325 mm	0-25 mm	150-175 mm	300-325 mm	0-25 mm	150-175 mm	300-325 mm	450-475 mm
8.0 kg/m <sup>3</sup>													
Original	8.19 (9.73)	3.59 (4.25)	2.06 (1.88)	2.88 (3.37)	0.50 (0.38)	0.17 (0.10)	0.20 (0.11)	0.39 (0.41)	0.21 (0.19)	0.16 (0.04)	0.24 (0.21)	0.15 (0.09)	
Replaced	1.41 (0.28)	0.91 (0.34)	0.94 (0.31)	3.07 (3.10)	0.31 (0.17)	0.18 (0.15)	0.11 (0.05)	0.67 (0.61)	0.20 (0.02)	0.13 (0.00)	0.34 (0.24)	0.22 (0.16)	
12.0 kg/m <sup>3</sup>													
Original	7.16 (8.36)	2.19 (3.34)	1.74 (2.27)	3.34 (2.48)	0.45 (0.42)	0.43 (0.60)	0.68 (0.51)	0.37 (0.48)	0.35 (0.41)	0.26 (0.36)	0.80 (1.26)	0.32 (0.23)	
Replaced	2.18 (1.33)	3.09 (4.21)	2.19 (2.35)	1.76 (2.08)	0.77 (0.99)	0.09 (0.03)	0.15 (0.16)	0.49 (0.42)	0.15	0.09	0.06	0.16	

<sup>a</sup>Numbers in parentheses represent one standard deviation. Where no standard deviation appears, only one sample was analyzed.

posts than in the next 37 mm, but none of the levels approached the original respective target retention. The presence of elevated preservative levels on the surface suggests that extensive depletion of preservative components has not occurred, since depletion is most likely to occur nearer the wood surface. The differences in surface retentions between the below- and above-ground samples, however, suggest that some depletion has occurred over the prolonged exposure.

The exposed cells along the cross section of a wood sample are far more likely to sorb higher amounts of preservative during treatments than the radial or tangential faces. Once in service, the end-grain is also more likely to lose preservative at a faster rate. Sampling the soil directly beneath selected posts for metal content revealed that copper, chromium, and arsenic were all at slightly elevated levels immediately beneath the post and 300 mm below that zone, but were at background levels at the deepest sampling point (Table 6).

The formulation used to treat these posts was similar to CCA Type B, which contains higher levels of arsenic than would be present in the currently used Type C formulation (Table 7). The higher arsenic levels and correspondingly lower chromium levels should result in less complete fixation and higher leaching losses. As a result, metal levels, particularly arsenic, should be higher in the soil than would be found with wood treated with CCA Type C. A comparison of specified arsenic proportions with those found in the posts suggests that some depletion has occurred in soil contact. For example, arsenic represents 27% of the total CCA in the outer zone of samples taken 150 mm below ground and 42% in samples taken 300 mm above ground in posts treated to 8 kg/m<sup>3</sup>. Similar effects were noted for the higher retentions and suggest that some metal redistribution has occurred in the wood.

*Metal levels beneath CCA-treated southern pine stakes*

Although not the primary focus of the study, soil samples were also removed from

TABLE 5. Copper, chromium, and arsenic retention in CCA (Type B)-treated southern pine posts exposed near Gainesville, Florida, for 47 years.<sup>a</sup>

Retention	Post history	Distance above ground line (mm)	Assay zone	Metal retention (kg/m <sup>3</sup> )			
				As <sub>2</sub> O <sub>5</sub>	CrO <sub>3</sub>	CuO	Total
8.0 kg/m <sup>3</sup>	Original	-150	inner	0.529 (0.58)	1.065 (1.07)	0.647 (0.54)	2.241 (2.19)
			outer	0.961 (0.63)	1.924 (0.78)	0.696 (0.10)	3.581 (1.51)
	Replaced	-150	inner	1.077 (1.07)	0.65 (0.66)	0.292 (0.30)	2.019 (2.03)
			outer	1.987 (0.95)	1.79 (0.77)	0.966 (0.37)	4.743 (2.09)
		300	inner	0.57 (0.45)	1.154 (0.67)	0.926 (0.32)	2.650 (1.45)
			outer	0.837 (0.33)	2.085 (0.43)	0.679 (0.22)	3.601 (0.98)
12.0 kg/m <sup>3</sup>	Original	-150	inner	1.686 (0.63)	1.066 (0.45)	0.623 (0.40)	3.375 (1.48)
			outer	2.189 (0.61)	2.084 (0.43)	1.148 (0.31)	5.421 (1.35)
		300	inner	0.855 (0.73)	1.386 (0.75)	1.096 (0.72)	3.337 (2.19)
			outer	2.723 (1.68)	3.669 (1.67)	0.864 (0.34)	7.256 (3.68)
	Replaced	-150	inner	2.297 (1.41)	1.284 (0.73)	0.717 (0.46)	4.298 (2.60)
			outer	3.518 (1.87)	3.094 (1.62)	1.507 (0.83)	8.119 (4.33)
		300	inner	1.757 (0.57)	1.965 (0.48)	1.386 (0.50)	5.108 (1.54)
			outer	3.855 (1.36)	4.326 (0.95)	1.245 (0.40)	9.425 (2.71)
	Replaced	-150	inner	2.739 (1.43)	1.493 (0.75)	0.818 (0.40)	5.050 (2.57)
			outer	4.979 (1.40)	4.009 (0.90)	2.102 (0.63)	11.091 (2.92)

<sup>a</sup> Numbers in parentheses represent one standard deviation. Where no standard deviation appears, only one sample was analyzed.

beneath southern pine stakes treated with CCA to a retention of 23 to 24 kg/m<sup>3</sup> and exposed for 44 years at the Gainesville plot. Copper and chromium levels were elevated immediately beneath the stakes, but concentrations declined sharply 450 mm beneath the bottom of the stake and reached background levels within 900 mm (Table 8). Arsenic levels were within background levels at all of the sampling depths and were at the limit of detection 1,350 mm below the stake. These results suggest that metals can migrate, but the degree of downward movement from the treated posts was minimal.

TABLE 6. Residual metal levels beneath the exposed end-grain of southern pine posts treated with 12 kg/m<sup>3</sup> of CCA (Type B) and exposed for 47 years near Gainesville, Florida.<sup>a</sup>

Depth beneath post (mm)	Residual metal level (ppm)		
	Copper	Chromium	Arsenic
0	18.3 (10.2)	0.60 (0.05)	1.09 (0.66)
300	5.5 (6.6)	0.41 (0.04)	2.41 (2.48)
1,200	0.3 (0.1)	<0.02	<0.05

<sup>a</sup> Values represent means of two samples. Values in parentheses represent one standard deviation.

## CONCLUSIONS

CCA components migrated from posts treated with CCA Type B into the surrounding soil, but the concentrations declined rapidly with both distance from the post and depth below the soil surface. The results suggest that soil contamination after 45 years of exposure is minimal.

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TABLE 7. Relative proportions of copper, chromium, and arsenic in chromated copper arsenate (CCA) solutions (oxide basis).<sup>a</sup>

CCA type	Proportion in solution (% oxide basis)		
	CuO	CrO <sub>3</sub>	As <sub>2</sub> O <sub>5</sub>
Type A	18.1	65.5	16.4
Type B	19.6	35.3	45.1
Type C	18.5	47.5	34

<sup>a</sup> Source: Standard P5 (American Wood Preserver's Association 1999).



TABLE 8. Residual metal levels beneath four southern pine sapwood stakes treated with CCA (Type B) to a retention of 23 to 24 kg/m<sup>3</sup> and exposed for 44 years near Gainesville, Florida.

Depth beneath stake (mm)	Residual metal levels (ppm)		
	Copper	Chromium	Arsenic
0	71.4 (56.0)	1.75 (0.44)	0.22 (0.10)
450	6.5 (7.5)	0.24 (0.19)	0.32 (0.28)
900	1.7 (2.6)	0.12 (0.07)	0.06 (0.02)
1,350	0.1	<0.02	<0.05

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